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Pre-stabilized Energy-optimal Model Predictive Control for Point-to-Point Motions

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1 Abstract

This presentation proposes Pre-stabilized Energy-optimal Model Predictive Control (Pre-stabilized EOMPC) which is an extension of our previous research - Energy-Optimal Model Predictive Control (EOMPC) approach. In the Pre-stabilized EOMPC, a 'pre-stabilization' strategy is utilized to reduce the computational load of the EOMPC. Pre-stabilization uses deadbeat state feedback to modify the system models employed in the formulation of MPC and yields a sparse optimization problem. The computational efficiency and performance of EOMPC with pre-stabilization is validated through numerical simulations.

2 Pre-stabilized EOMPC

EOMPC [1] is a control method to realize energy-optimal point-to-point motions within a required motion time. It determines the control signal by solving on-line, at every sampling time, an optimal control problem, based on the current state of the *open-loop* system model as shown in Fig 1.

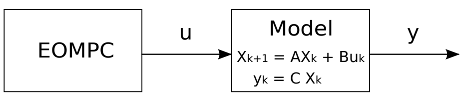

Figure 1: The EOMPC approach is based on an open-loop model

Pre-stabilized EOMPC is developed based on EOMPC. The pre-stabilized EOMPC approach calculates the optimal control sequence based on a *closed-loop* system model as illustrated on Fig. 2.

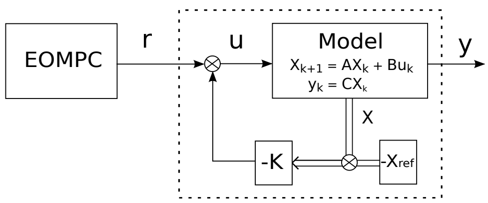

Figure 2: Control scheme of pre-stabilized EOMPC

Constructing the closed-loop system model is called *pre-stabilization*. The dead-beat state-feedback controller K is calculated using the pole placement approach such that all poles of this closed-loop system model are located at zero, the origin of the z-plane. It is the key to yield sparse MPC optimization problems.

3 Numerical validation

The considered system is the linear motor of a badminton robot setup developed at Flanders' Mechatronics Technology Centre (FMTC). This linear motor is used to position the badminton robot across the field and is the main energy consumer of this setup. The dynamics of this linear motor relating the motor current and position are modelled as a double integrator. The considered limits on position, velocity, and acceleration are: $\pm 1.9[m]$, $\pm 3[m/s]$, $\pm 30[m/s^2]$ respectively.

Figure 3 shows the simulation result for a motion of $1[m]$. The required motion time is $0.5[s]$, requested at time $0.1[s]$. Using pre-stabilized EOMPC and EOMPC, both implementations yield exactly the same motion. However, the CPU time is quite different. Since the pre-stabilization results in sparse MPC optimization problem, the resulting CPU time has one peak ($8.6[ms]$) at $t = 0.1[s]$. The worst CPU time of EOMPC is 4 times larger than that of the pre-stabilized EOMPC which is $32.54[ms]$.

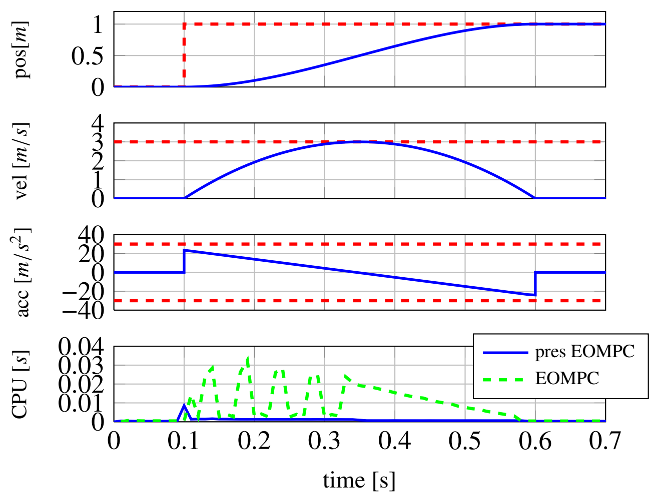

Figure 3: Performance of the system and CPU time

References

[1] X. Wang, J. Stoev, G. Pinte and J. Swevers. Classical and modern methods for time-constrained energy optimal motion Application to a badminton robot, Mechatronics, Volume 23, Issue 6, September 2013, Pages 669-676.

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